DTIC FILE COPY

(4)

MARINE PHYSICAL LABORATORY

SCRIPPS INSTITUTION OF OCEANOGRAPHY

San Diego, California 92152

PROGRAM IN MARINE PHYSICS APPLIED TO NAVY UNDERSEA MISSIONS

AD-A206 586

Kenneth M. Watson, Principal Investigator

Final Report Prepared for Office of Naval Research Contract N00014-87-K-0225 for the Period November 1, 1986 through January 31, 1988. Total Award: $984,000.

MPL-U-37/88
October 1988

Approved for public release; distribution unlimited.

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) MPL-U-37/88	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Marine Physical Laboratory; 6b. OFFICE SYMBOL (If applicable) MPL	7a. NAME OF MONITORING ORGANIZATION Office of Naval Research Department of the Navy
6c. ADDRESS (City, State, and ZIP Code) University of California, San Diego Scripps Institution of Oceanography San Diego, CA 92152	7b. ADDRESS (City, State, and ZIP Code) 800 North Quincy Street Arlington, VA 22217-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Office of Naval Research; 8b. OFFICE SYMBOL (If applicable) ONR	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00014-87-K-0225
8c. ADDRESS (City, State, and ZIP Code) Department of the Navy 800 North Quincy Street Arlington, VA 22217-5000	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
FINAL REPORT - Program in Marine Physics Applied to Navy Undersea Missions

12. PERSONAL AUTHOR(S)
Kenneth M. Watson, Principal Investigator

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Summary	FROM ______ TO ______	October 1988	13

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	The SIO Marine Physical Lab. (MPL)

19. ABSTRACT

This final report described work performed by the Marine Physical Laboratory (MPL) in support of Navy Undersea Missions.

The MPL Horizontal and (Vertical) Digital Acoustic Array was completed. This array can be deployed with a maximum length of 1.5 km. It operates in the 10-200 Hz range. The array was deployed in January 1977 from ORB. Element navigation was tested ~~from ORB~~ in March 1987 and an engineering deployment was made from FLIP in June 1987.

This array was again deployed from FLIP in September 1989 as part of the SVLA experiment. Ambient noise and signals from acoustic sources were recorded. Data analysis from this experiment is continuing.

The MPL Swallow Float Acoustic Array was deployed in September 1987 as a part of the SVLA experiment. The data from this deployment is being used to determine flow and strum contamination in the SVLA array.

A high resolution Doppler velocity sensing sonar was developed. This sonar will operate in either a coherent mode (1 km range resolution, 50 m range) or in an incoherent mode with 400 m range). The sonar has provided data describing small-scale velocity shears in the upper ocean. It is scheduled to be deployed in the 1989 CEAREX experiment in the Arctic Ocean. Keywords: Acoustic arrays; High resolution sonar, (edc)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Kenneth M. Watson	22b. TELEPHONE (Include Area Code) (619) 534-1803; 22c. OFFICE SYMBOL MPL

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

☆ U.S. Government Printing Office: 1986—607-044

A

PROGRAM IN MARINE PHYSICS APPLIED TO NAVY UNDERSEA MISSIONS

Kenneth M. Watson, Principal Investigator

Final Report Prepared for Office of Naval Research
Contract N00014-87-K-0225 for the Period November 1, 1986
through January 31, 1988. Total Award: \$984,000.

This final report described work performed by the Marine Physical Laboratory (MPL) in support of Navy Undersea Missions.

The MPL Horizontal and (Vertical) Digital Acoustic Array was completed. This array can be deployed with a maximum length of 1.5 km. It operates in the 10-200 Hz range. The array was deployed in January 1977 from ORB. Element navigation was tested from ORB in March 1987 and an engineering deployment was made from FLIP in June 1987.

This array was again deployed from FLIP in September 1989 as part of the SVLA experiment. Ambient noise and signals from acoustic sources were recorded. Data analysis from this experiment is continuing.

The MPL Swallow Float Acoustic Array was deployed in September 1987 as a part of the SVLA experiment. The data from this deployment is being used to determine flow and strum contamination in the SVLA array.

A high resolution Doppler velocity sensing sonar was developed. This sonar will operate in either a coherent mode (1 km range resolution, 50 m range) or in an incoherent mode with 400 m range). The sonar has provided data describing small-scale velocity shears in the upper ocean. It is scheduled to be deployed in the 1989 CEAREX experiment in the Arctic Ocean.

PROJECT: High Gain, High Resolution Studies of the Vertical Directionality of Ambient Noise and Sound Propagation

PROJECT LEADER: Frederick H. Fisher, Research Oceanographer, (619) 534-1796
Victor C. Anderson, Prof. Applied Physics, (619) 534-1793
John A. Hildebrand, Assist. Res. Oceanographer, (619) 534-4069
William S. Hodgkiss, Associate Professor, (619) 534-1798

Preliminary Expedition Report for October 1987 Vertical Line Array Experiment - R/P FLIP

The Vertical Line Array Experiment, conducted during September 1987, was designed to study acoustic propagation and noise at low frequencies. An acoustic array of 120 hydrophones deployed vertically from R/P *FLIP* collected 19 days of almost continuous recordings. Two low frequency acoustic sources (HLF-3 and HX-90) transmitted over 11 days at frequencies ranging from 11 Hz to 200 Hz. Environmental measurements collected during the experiment included SVP, CTD, XBT, AXBT profiles as well as current, wind speed, swell height, air temperature and ship sightings. Ambient acoustic noise measurements collected throughout the experiment may be correlated with the varying environmental conditions encountered (5-25 knot winds, 0-6 m swell). Preliminary (at sea) data processing indicate that the acoustic transmissions (both cw tones and coded sequences) above 50 Hz are observed with large S/N. Acoustic transmissions below 50 Hz require additional processing and array gain for detection. Figure 1 shows a time-line for array recording, acoustic transmission and environmental data collected during the VLA deployment.

Array Configuration

The vertical line array consisted of 120 hydrophone elements spaced at 7.5 meters apart for a 900 m aperture and a half-wave length frequency of 100 Hz. Almost continuous recordings were collected of 120 acoustic channels at a 500 Hz sample rate and 12 navigation channels at a 2.5 kHz sample rate. The low frequency acoustic signals were filtered, providing a 10 - 250 Hz pass band. The high frequency navigation signals were narrow band filtered at 12 kHz.

Acoustic navigation of the array was conducted using three bottom transponders in a triangular configuration at approximately 1 nm in horizontal range from *FLIP* and a 12 kHz transmitter/receiver pair mounted on the bottom of *FLIP*. The transponders were interrogated from *FLIP* and the transponder replies were recorded by the navigation channels in the array. The location of *FLIP* relative to the transponders was recorded once per hour during the experiment.

Acoustic ambient noise, MLS coded sequences and narrow-band tone data were recorded with the top of the array at 3 different depths so that hydrophones spanned

the water column from 400 to 3100 meters. Long term records were obtained from continuous observations for 10 days with the array spanning 400-1300 m depth.

A beam pattern test was conducted with the HX-90 at approximately 1 nm in range and 300 m in depth transmitting at 175 and 200 Hz. The test commenced with the top of the array at 2241 m and both frequencies were recorded at 75 m increments as the array was raised to the surface.

In addition to the VLA a variety of low frequency sensors were deployed for one day during the period of long range acoustic transmissions. These sensors included VLF Sonobouys, freely-drifting Swallow Floats, and Ocean-Bottom Seismographs. Direct comparison between these sensors and the VLA should yield information on their relative sensitivity to VLF transmissions.

Acoustic Transmissions

During the VLA experiment acoustic signals were generated by two different low frequency sources: an HLF-3 deployed from the USNS *De Steiger* and an HX-90 deployed from the USNS *Narragansett.* These acoustic signals spanned the VLF frequency band, ranging in frequency from 11 Hz to 200 Hz. Both continuous wave tones and MLS coded sequences were transmitted. CW tones included 11, 16, 21, 27, 41, 56, 81, 98, 115, 135 and 159 Hz and coded sequences were at 60 - 100 Hz as well as at 175 -225 Hz. These signals were transmitted for approximately 10 days at a range of several convergenze zones from the receiving array. An additional day of acoustic transmissions was divided between 5 intermediate waypoints. For 6 hours each day the transmitting ship location and *FLIP* location were determined by GPS navigation. During the long-range transmissions the source was acoustically navigated within a transponder net to yield its location with an accuracy of a few meters.

Environmental Measurements

Environmental measurements were collected throughout the experiment by the three seagoing vessels and by coordinated P-3 flights. These measurements were directed toward characterizing the sound velocity profile between the acoustic source and vertical line array as well as characterizing environmental noise sources. During the 10 day period of long range acoustic transmissions daily CTD casts (17 total) were conducted by the source ship (*De Steiger*) and at least twice daily XBT casts (52 total) were conducted by the receiving ship (*FLIP*). The *Narragansett* made two along-track SVP surveys with 20 nm spacing during this period (75 total SVPs). In addition, two P-3 flight conducted AXSV surveys with 20 nm spacing, one at the beginning and one a the end of the long range transmission period. Immediately following this period the *De Steiger* conducted 22 CTD casts at locations between the source and VLA receiver. Two current meters were operated at 50 and 100 m depth from *FLIP* to indicate the current flow in the vicinity of the VLA. The combination of these surveys will yield a detailed record of the sound propagation environment during the experiment.

Potential environmental contributors to acoustic ambient noise were also recorded. On an hourly basis the wind velocity, swell height and ship sightings were recorded at *FLIP*. In addition, two ship location surveys were conducted by P-3 flights.

Preliminary Results

CW Tones: CW tones above 50 Hz were identified at individual phones using 11 incoherently averaged 1892 PT FFTs (98 sec. of data). A large variation in tonal signal to noise ratio was observed over the array aperture (5 to 35 dB S/N @81 Hz). Further narrow-band processing is required to identify the CW tones below 50 Hz transmitted at long range. These low frequency tones and their harmonics were observed in transmissions at close range.

MLS: The 80 Hz MLS sequence was identified at a long-range cross-correlating the received signal with a replica of the transmitted sequency. Up to 9 individual acoustic returns were observed from a single transmission. There was a general correspondence between the observed arrival times and the predicted arrivals across the array.

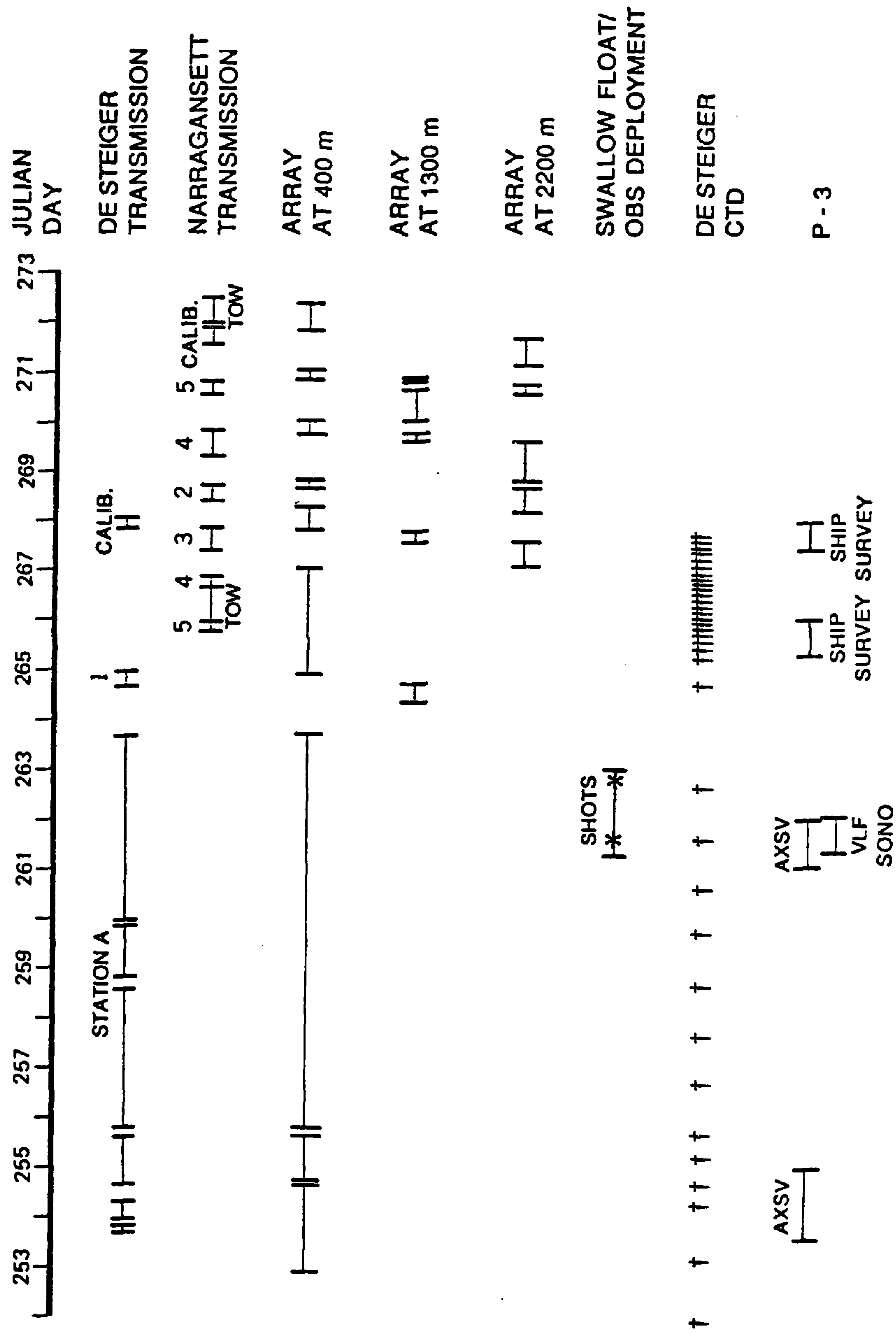
Ambient noise: Ambient noise spectral shape was closely correlated with historical spectra for areas of heavy shipping traffic. Long term data showed an increase in ambient noise levels above $\sim$ 100 Hz with increasing wind speed, particularly for the upper portions of the array.

Navigation: Preliminary acoustic navigation of the array indicated that the 12 kHz system operated properly and the array was nearly vertical. Accurate transponder locations will be calculated from 12 kHz data acquired by the *Narragansett.*

FLIP and *Narragansett*: GPS positions will be used to locate the transponder network with respect to the acoustic source. Acoustic navigation of the HLF 3 will provide detailed source location.

In summary, the VLA Experiment has produced a rich data set of low frequency acoustic propagation and noise. Both the acoustic source and receiving array performed well throughout the experiment. Acoustic navigation of source and receiver will allow position corrections to be calculated. Extensive environmental data may allow for accurate modeling of the acoustic propagation.

Figure I. Time line for array, acoustic transmission and environmental data collected during the VLA Experiment, September 1987.



PROJECT: Horizontal Digital Acoustic Array for Study of Residual Noise

PROJECT LEADER: John A. Hildebrand, Assist. Prof. of Geophysics, (619) 534-4069

The objective of this project was to develop a large horizontal acoustic array capable of studying the distribution of low frequency (10-200 Hz) noise in the ocean. The horizontal array was constructed and a successful horizontal array test deployment was conducted. However, before a data collection expedition could be conducted, our efforts were redirected to construction of a vertical array for the ONT Single Vertical Line Array (SVLA) experiment of September 1987. The horizontal array was modified for operation as a vertical array and successfully recorded 120 channels of acoustic data for the 14 day duration of the experiment.

History of Horizontal/Vertical Array Development

During March 1985 the MPL horizontal array underwent a deployment and retrieval sea-going exercise. A 1.5 km nylon line was deployed in a horizontal mooring to test the array deployment and retrieval operations. During August 1986 the horizontal array underwent a sea-trial in the California borderlands in 1050 m of water. Horizontal array deployment and retrieval procedures were improved and reduced to a routine operation. A problem was experienced with breaking of array pressure case connectors during this deployment, especially when the deployment ship was poorly aligned with the face of FLIP during the initial stages of deployment. Five array subsections were tested electrically during the deployment and were found to reliably work in concert. During January 1987 the array was deployed from the research platform ORB; telemetry accuracy was tested and found to be adequate for a complete 12 section array (120 channels). During March 1987 array element navigation was tested from the ORB using a network of bottom-moored acoustic transponders. During June 1987 the array was deployed in the vertical mode from FLIP and an engineering test was conducted of array noise performance and navigation. The SVLA expedition was conducted during September 1987 and a complete 120 channel vertical array was deployed. The array met all performance requirements for the experiment, accurately recording both long-range sound transmissions and acoustic ambient noise.

MILESTONES

FY85

March 1985 - Sea-test of horizontal array mooring procedures with FLIP.

FY86

August 1986 - Sea-test of 50 element horizontal array moored from FLIP.

FY87

January 1987 - Sea-test of 120 element array suspended from ORB.

March 1987 - Sea-test of array element navigation from ORB.

June 1987 - Sea-test of vertical array suspended from FLIP.

September 1987 - SVLA Expedition, 120 element vertical array suspended from FLIP.

PROJECT: Very Low Frequency Ambient Noise Observations

PROJECT LEADER: William S. Hodgkiss, Associate Professor, (619) 534-1798
Victor C. Anderson, Professor Applied Physics, (619) 534-1793

Flow noise has been a serious limitation to the measurement of the true ambient infrasonic acoustic background noise in the 1-20 Hz band. Even the very low water velocities associated with deep ocean bottom currents create turbulent pressures that obscure measurements in the region. The obvious solution is to have an array whose elements do not move relative to the surrounding water. The Swallow float, a buoy which is less compressible than water, is a device which acts as a Lagrangian particle, moving with the water and thus is a suitable platform for support of an infrasonic receiving array element.

The element of the MPL Swallow float array is a spherical glass Swallow float which contains three geophones as directional infrasonic receivers, a compass for buoy heading, an acoustic pinger/transponder for localization, a solid state memory data buffer, a digital tape data recorder, and an acoustically actuated ballast release. Several of these elements can be deployed in a random configuration to create a spatially distributed array. Each buoy records the sampled and digitized infrasonic data continuously and periodically records compass heading and arrival times of the "roundrobin" pinger/transponder pulses and echoes.

After recovery of the buoys, the time bases can be synchronized from the reciprocal travel path times of the pinger pulses. Then the travel time data can be used to determine the relative location of each buoy as a function of time, and finally, the infrasonic element data can be combined coherently to form directional beams for analysis of the spatial structure of the noise field.

In this program, twelve (12) Swallow floats were taken to sea and deployed as a freely drifting vertical array of VLF sensors. The buoys were deployed adjacent to the 900 m aperture vertical array deployed during the High Gain Initiative SVLA experiment in September 1987. Currently, the data from this experiment is being analyzed in an effort to ascertain the flow and strum contamination present in the SVLA array.

PROJECT: High Resolution Velocity Sensing

PROJECT LEADER: Robert Pinkel, Assoc. Res. Oceanogr., (619) 534-2056

Fine Scale Shear

The fine scale shear field in the sea plays a major role in dispersing sub-surface signatures which might be usefully tracked. In quantifying the preformance of any potential non-acoustic detection system it is necessary to know both the spatial and temporal structure of the natural background shear. Prior to this program, the space-time behavior of the fine scale shear was inferred directly from the larger scale, more easily measured shear field.

Spectral models such as those proposed by Garrett and Munk (1972,1975), were used to quantify the predictions. The models featured many simplifying assumptions, some of which lead to unrealistic predictions. Such was the case for the fine scale shear field. The models predicted that the fine scale shear would have the same, slow characteristic evolution time as the large scale shear. If this were the case, any rapidly changing shear event must presumably be man-made, and would be easily detected. If the natural background shear changes on a faster time scale at small-length scales than at large, contrary to the model assumptions, the non acoustic detection problem will be much different.

It is appropriate to actually go to sea and look at the combined depth-time variability of the shear, to settle this issue. Such a program was proposed, using pulse to pulse coherent sonar technology. It was subsequently funded under the present contract.

A four beam 161 kHz sonar system was constructed during the late 1985 and early 1986, for use from the research platform FLIP (Fig. 1). The sonar had a maximum range of 50m in the coherent mode (400m in the more conventional pulse-to-pulse incoherent mode of operation), with $1~m sup 3$ range resolution. It was first operated at sea in a January 1986 test cruise, and subsequently run for a 7.5 day continuous run in the October 1986 PATCHEX experiment. Data were collected over the depth range 130-175m in a variety of environmental conditions.

With the sonar transmitting 20 times per second, and shear profiles being estimated every 1.6 sec, a wealth of information was obtained on the fine scale shear field in PATCHEX. It is appropriate to point out two fundamental results of the program to-date. First, the time scales of the fine scale shear were indeed was vastly different than extrapolation from larger scale would predict (Fig. 2). Rapidly varying small scale shear is much more common in the upper ocean than the models predict. This greatly alters the complexion of the non acoustic detection problems.

A second deliverable from this component of the program is an estimate of the ultimate performance limit attainable using the acoustic Doppler technique. The incoherent precision of the coherent Doppler sonar was sufficiently high that the dominant measurement noise was associated with the swimming of the targets, mainly

zooplankton. Swimming activity was found to exhibit a strong diurnal behavior (Fig. 3). This, of course, is no surprise to biologists. The surprising aspect is that swimming speeds are significant compared to those which need to be resolved for the non-acoustic detection problem. The effects of scatterer swimming noise can be reduced by choice of sonar operating frequency and scattering volume dimension. To the extent that scattering sonars might themselves prove useful as non-acoustic detection systems, the minimization of "scatterer swimming noise" will be a key element in the system design.

The coherent sonar developed for this program is presently being reconfigured for deployment in the 1989 CEAREX experiment in the Arctic Ocean. Here it will be suspended under the sea ice and operated in a hybrid coherent/incoherent mode. The under-ice boundary layer will be sensed coherently. The ambient internal wave/shear field will profile to 400m depths in the incoherent mode. Following CEAREX, we hope to modify the sonar for deep ocean use. This involves the deployment of a signal multiplexing system for the sonar, which will enable the use of a less expensive cable to suspend the instrument. Funds for this development are presently being sought.

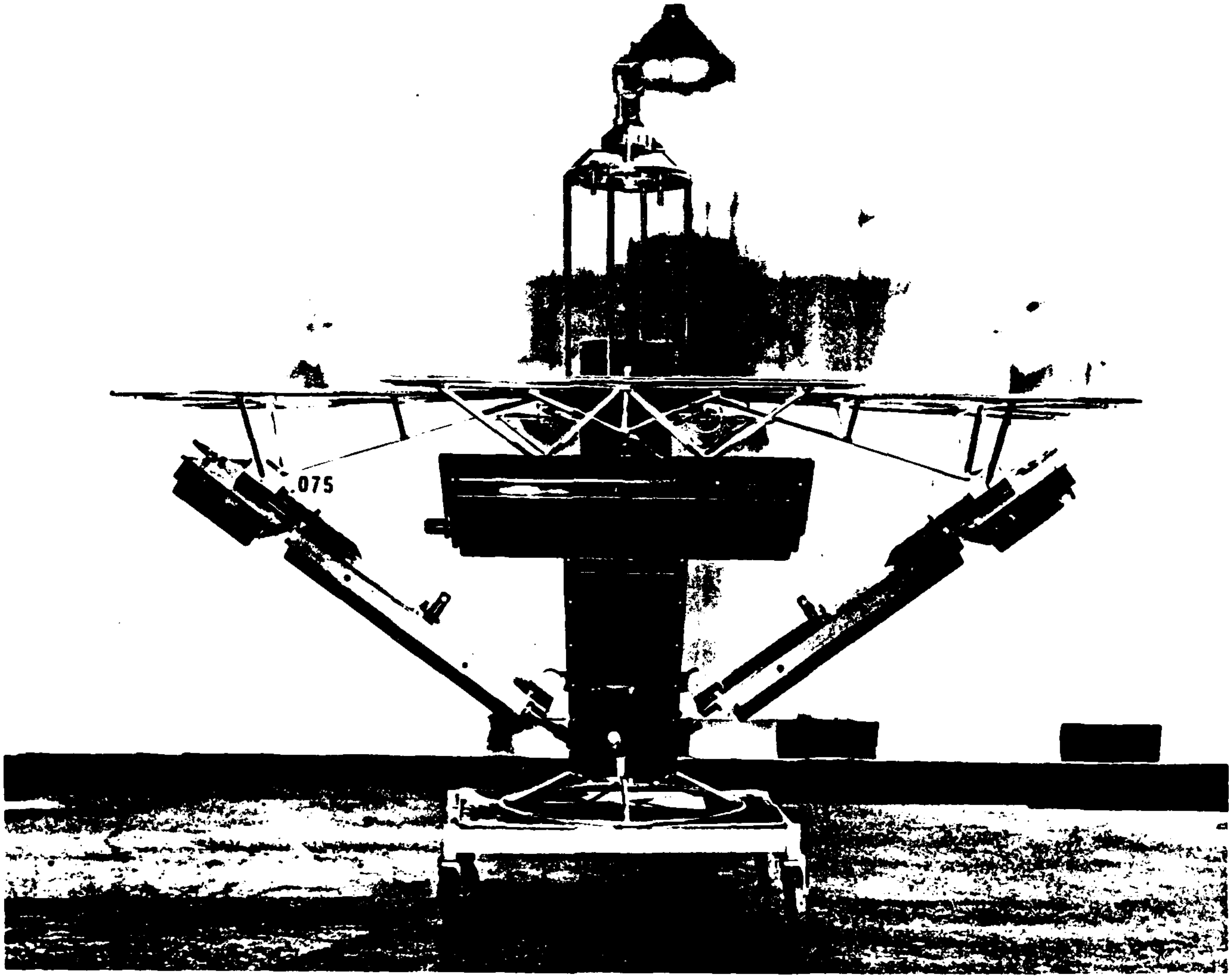


Figure 1. A coherent sonar developed at the Marine Physical Laboratory, for upper ocean studies. The four beam system operates at 160 kHz. It has a range of 25-50 m, with a resolution volume of several cubic meters.

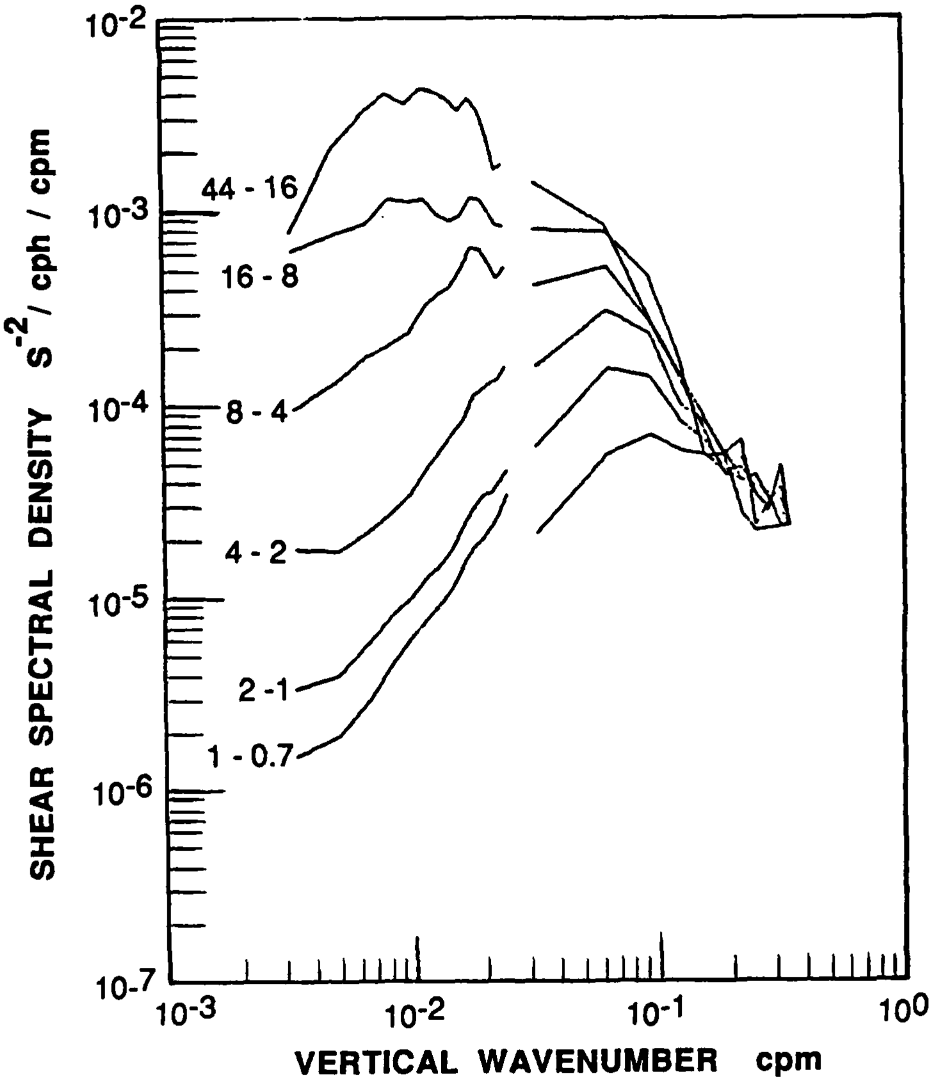


Figure 2. A wavenumber frequency spectrum of the shear. Cross sections are plotted as a function of vertical wavenumber at frequency bands corresponding to periods of 44-16 hrs to 1-.7 hrs. The large-scale information on the left comes from the MPL 75 kHz incoherent sonar system. Small-scale information, on the right, is provided by the coherent sonar.

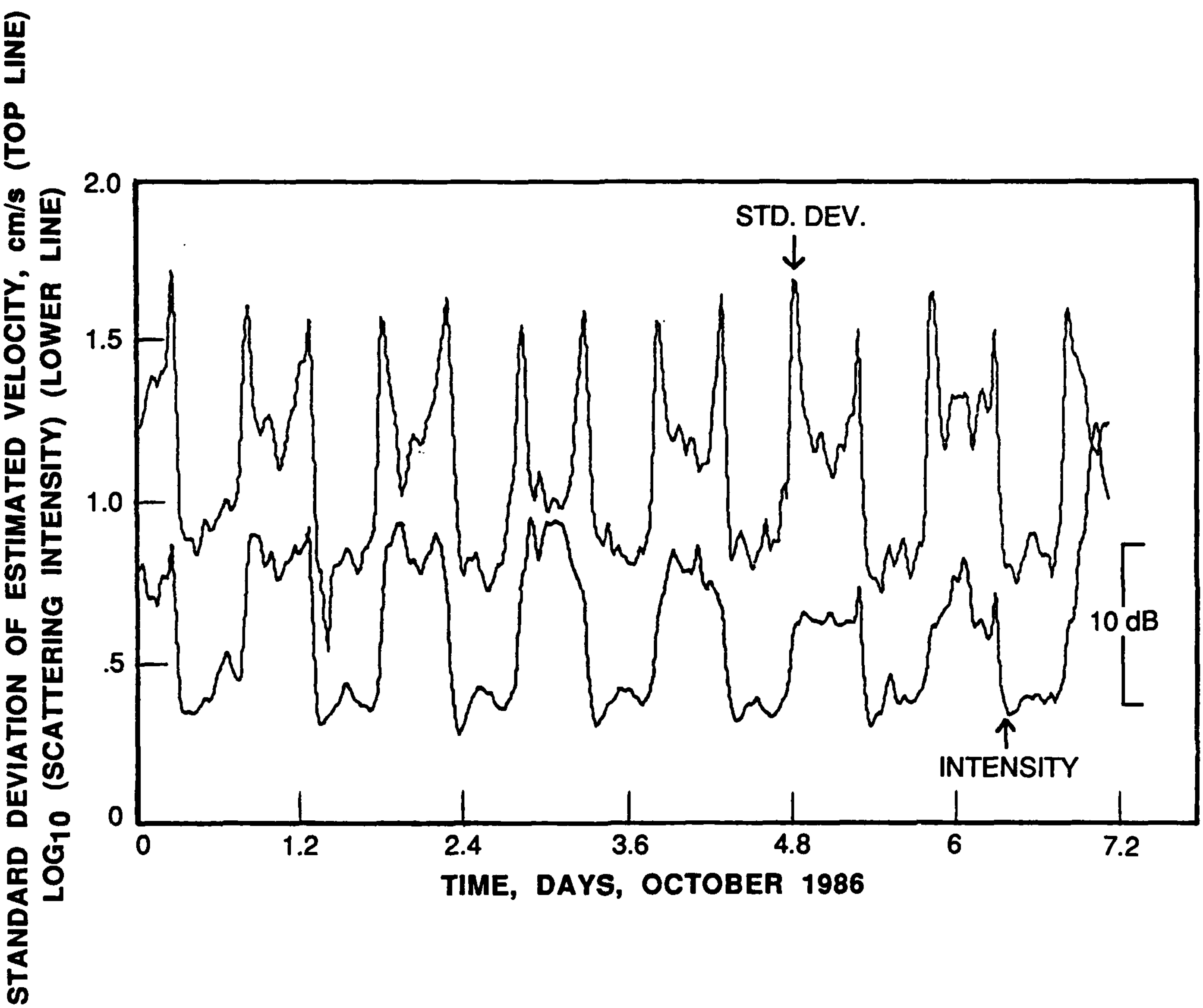


Figure 3. A comparison of sonar accuracy and scattering strength. Note that inherent accuracy is reduced by nearly a factor of two during the peak migration periods at dusk and dawn.

ONR/MPL GENERAL DISTRIBUTION LIST

Chief of Naval Research
Department of the Navy
Arlington, Virginia 22217-5000
Code 12, 122(2), 102C
111, 112, 113,
1122PO, 425-AC, 460

ONRDET
NSTL Station
Bay St. Louis, Mississippi 39529-5004
Code 112, 1121, 1122CS, 422CB,
1122PO, 1125GG

Director
Office of Naval Research
Branch Office
1030 East Green Street
Pasadena, California 91106-2485

Commander
Naval Sea Systems Command
Washington, D. C. 20362
Code 63, 63R, 63R-23

Commanding Officer
Naval Ocean Research and
Development Activity
NSTL Station
Bay. St. Louis, Mississippi 39529-5004
Code 100, 110, 300, 330,
340, 350, 360, 500

Commander
U.S. Naval Oceanographic Office
NSTL Station
Bay St. Louis, Mississippi 39522-5004
Atten: Bill Jobst

Assistant Secretary of the Navy
(Research Engineering & Systems)
Department of the Navy
Washington, D. C. 20350

Defense Advanced Res. Proj. Agency
TTO - Tactical Technology Office
1400 Wilson Boulevard
Arlington, Virginia 22209-2308
Atten: Capt. Kirk Evans

National Oceanic & Atmospheric
Administration
Ocean Engineering Office
6001 Executive Boulevard
Rockville, Maryland 20852

Commander
Space and Naval Warfare
Systems Command
Washington, D. C. 20360
Code PDW-124, 320A

Commander
Naval Ship Res. & Dev. Center
Bethesda, Maryland 20084

Executive Secretary
Naval Studies Board
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Director
Strategic Systems Proj. Ofc. (PM-1)
Department of the Navy
Washington, D. C. 20361
Code NSP-2023

Commander
Naval Ocean Systems Center
San Diego, California 92152
Code 00, 01, 16, 94, 531
5301, 71, 72

Commander
Submarine Development Group ONE
Fleet Post Office
San Diego, California 92152

Commanding Officer
Civil Engineering Laboratory
Naval Construction Battalion Center
Port Hueneme, California 93043
Code L40, L42

Commanding Officer
Naval Underwater Systems Center
Newport, Rhode Island 20844
Atten: Dr. K. A. Kemp, Code 8213

Officer in Charge
Naval Underwater Systems Center
New London Laboratory
New London, Connecticut 06320
Code 900, 905, 910, 930, 960

Director of Research
U.S. Naval Research Laboratory
Washington, D. C. 20375
Code 2620, 2627, 5000, 5100, 5800

Commander
Naval Surface Combat Systems Center
White Oak
Silver Spring, Maryland 20910

Commanding Officer
Naval Coastal Systems Laboratory
Panama City, Florida 32401

STOIAC
Battelle Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

Commander
Naval Air Systems Command
Washington, D. C. 20361
Code 370

Commanding Officer
U.S. Naval Air Development Center
Attention: Jim Howard
Warminister, Pennsylvania 18974

Director
Defense Documentation Center
(TIMA), Cameron Station
5010 Duke Street
Alexandria, Virginia 22314

Institute for Defense Analyses
1801 North Beaugard Street
Arlington, Virginia 22311

Superintendent
U.S. Naval Postgraduate School
Monterey, California 93940

Chief Scientist
Navy Underwater Sound Reference Div.
U.S. Naval Research Laboratory
P.O. Box 8337
Orlando, Florida 32806

Supreme Allied Commander
U.S. Atlantic Fleet
ASW Research Center, APO
New York, New York 09019
Via: ONR 100 M, CNO OP092D1,
Secretariat of Military,
Information Control, Committee

Director
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

Director
Applied Physics Laboratory
Johns Hopkins University
Johns Hopkins Road
Laurel, Maryland 20810
Atten: J. R. Austin

Director
College of Engineering
Department of Ocean Engineering
Florida Atlantic University
Boca Raton, Florida 33431

Director
Marine Research Laboratories
c/o Marine Studies Center
University of Wisconsin
Madison, Wisconsin 53706

Director
Applied Research Laboratory
Pennsylvania State University
P.O. Box 30
State College, Pennsylvania 16802

Director
Applied Physics Laboratory
University of Washington
1013 East 40th Street
Seattle, Washington 98105

Director
The Univ. of Texas at Austin
Applied Research Laboratory
P.O. Box 8029
Austin, Texas 78712

Director
Lamont-Doherty Geological Observatory
Torrey Cliff
Palisades, New York 10964

Director
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

Director
Inst. of Ocean Science Engineering
Catholic University of America
Washington, D.C. 20017

National Science Foundation
Washington, D. C. 20550

Office of Naval Research
Resident Representative
c/o Univ. of California, San Diego
Mail Code Q023
La Jolla, California 92093

University of California, San Diego
Marine Physical Laboratory
Branch Office
La Jolla, California 92093